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ESTIMATING WEIGHTS OF LAMBS AT A CONSTANT AGE

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INTRODUCTION

In sheep-breeding experiments and in practical sheep breeding it is often desirable to have weights of lambs at a constant age for use in comparing the offspring of sires, comparing weights of lambs of different birth dates, and for making similar studies.

For the most part, a constant age of 20 weeks is used in the study of methods reported in this circular since it approximates weaning age of lambs. This is a convenient age for comparing offspring of different rams since at this age all the lambs born, except the ones lost from disease, weakness, and accident, are usually available for study. Initial culling may be done at this age or soon thereafter; therefore, the weight at 20 weeks is also convenient for comparing individual animals. The ages of 40 and 52 weeks are also used in extending the study to obtain results that can be used in practice.

The most accurate method of obtaining weights at a constant age is, of course, to weigh each lamb when it reaches that age. Such a procedure, however, is often impractical in experimental work and is especially so under farm and range conditions. The best substitute for weighing individual animals at a specific age is to weigh the entire flock or groups of lambs on a specified date or dates when the average age approximates the constant age desired. The weights at a constant age may then be estimated. The problem with which this circular deals is how these weights at a constant age may be most accurately estimated.

MATERIALS AND METHODS

The only method that has been generally used is to estimate the lamb's weight at the constant age on the basis of its rate of gain to the age at which it was weighed. This method is probably as accurate as any other so long as a linear growth rate prevails, but as the growth rate becomes less rapid an error will be introduced into the estimated weights. The reason for this is illustrated in figure 1, in which the growth curve of a group of Hampshire ram lambs, born as singles, is used as an example. This curve is based on weekly weights of 34 lambs and is the same as that for Hampshire male lambs presented in figure 2. Assuming the growth curve of an individual lamb to be that given in figure 1, line *be* represents the average weekly gain of this lamb to 15 weeks of age and if this rate of gain is assumed to continue to 20 weeks the estimated weight would be at *y*1. However, if this lamb has been weighed at 30 weeks instead of 15 weeks and the weights estimated on the basis of average weekly gain to 30 weeks, which is represented by line *bd*, the estimated weight at 20 weeks would be at *y*2. Therefore, the estimated weight based on the average daily or weekly gain to the time that an actual weight was taken would vary with the age at which the lamb was weighed. If it were weighed when younger than the constant age the estimated weight would be too high, whereas if it were weighed when older the estimated weight would be too low.

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* On November 1, 1939, Doctor Phillips became head of the Animal Husbandry Department, Utah State Agricultural College, Logan, Utah.

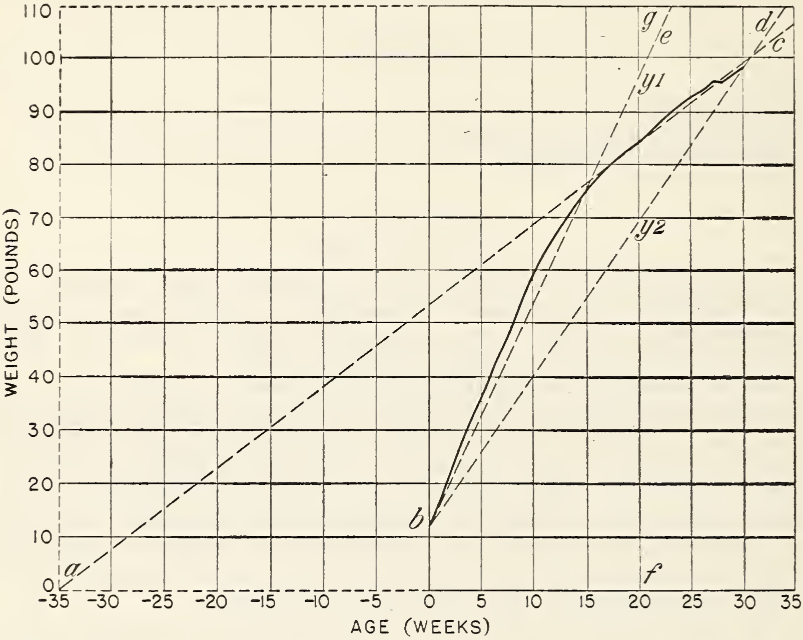

FIGURE 1.—Illustration of the principles involved in the two methods of estimating weights to a constant age, compared in this circular. The heavy line shows the average growth rate of a group of 34 ram lambs. Lines *be* and *bd* represent the average weekly gains from birth to 15 and 30 weeks of age, respectively, and *y*1 and *y*2 show the points to which weights would be adjusted if estimated along these lines. Line *ac* represents the slope of the growth curve between 15 and 30 weeks, and when extended intercepts the age axis at —35 weeks.

If a group of lambs were weighted on a date when they ranged in age from 15 to 30 weeks, it seems obvious that a closer approximation of the actual weight at 20 weeks should be obtained by estimating the weights along a line of approximately the same slope as the section of the growth curve involved than by correcting on the basis of average weekly gains. Line *ac* in figure 1 represents the line of best fit through the section of the growth curve between 15 and 30 weeks and when extended intercepts the age axis at −35 weeks. If the growth curves of several lambs of the same kind were plotted along with the curve in figure 1, these curves would tend to diverge as age increased. Because of this divergence, lines of best fit through the 15-to-30 weeks' section of the growth curves would not be parallel but would tend to converge at a common point on the age axis. If there is not too much variation in the points at which they intercept the age axis, a line from an average intercept to the weight attained by the individual lamb at a given age can be used in estimating its weight. The estimated weight is determined by the point on this line corresponding to the constant age (the point at which line *ac* crosses line *fg*).

In this circular a comparison is made of the accuracy of estimating weights at a constant age of 20 weeks (1) on the basis of weekly gains and (2) along a line of approximately the same slope as the section of the growth curve represented by the ages of the animals whose weights are being adjusted.

The estimating of weights by the first method was done according to the following formula:

$$\left(\frac{Z-B}{X}\right)20+B=Y,$$

in which Y=estimated weight, Z=actual weight, B=birth weight, X=actual age, and 20=constant age of 20 weeks. Thus, the estimated weight of a lamb weighing 40 pounds at 15 weeks and having a birth weight of 8 pounds would be computed as follows:

$$\left(\frac{40-8}{15}\right)20+8=50.7$$

The estimating of weights by the second method was done by the use of the following equation:

$$Z\left(\frac{20-A}{X-A}\right)=Y,$$

in which the symbols correspond to those used in the preceding equation, with the addition of A=intercept of age axis. If a group of Hampshire lambs is being studied which ranged in age from 15 to 30 weeks at the time weights were obtained, and the growth curve of Hampshires grown under those conditions is known, the first step is to determine the slope of a line that approximates this section of the growth curve. In the present study, this line of best fit was determined by the method of least squares, the calculations being based on the average weight at each point of the growth curve. This line is then extended to the point at which it intercepts the age axis (A). If the slope of this line is such that it intercepts the age axis at −35 weeks (for example, line *ac* in fig. 1), the weight of a lamb weighing 40 pounds at 15 weeks would be computed as follows:

$$40\left[\frac{20-(-35)}{15-(-35)}\right]=44$$

This method has been applied to swine by Bywaters and Willham [1] and Whatley and Quaife.[2]

Data from the flocks, consisting of Corriedale, Hampshire, Shropshire, and Southdown breeds, at the Agricultural Research Center at Beltsville, Md., were used in a study to compare the accuracy of estimated weights obtained by the two methods described. Lambs in these flocks were weighed once weekly during the first year of life. Therefore, for each lamb the actual weight taken within 3 days of the time it was 20 weeks of age was available, as well as data for plotting the average growth curves of the lambs grouped according to breed, sex, and type of birth (singles or twins). For purposes of this study it was assumed that all the lambs for a 6-year period had been weighed on the weighing date nearest to August 1, which would be within 3 days of that date, and that these were the only weights available on the lambs when they were approximately 20 weeks of age. Inspection of the data showed that most of the lambs of the Hampshire, Shropshire, and Southdown breeds ranged from 15 to 30 weeks of age on August 1 and the Corriedale lambs ranged from 20 to 35 weeks on that date.

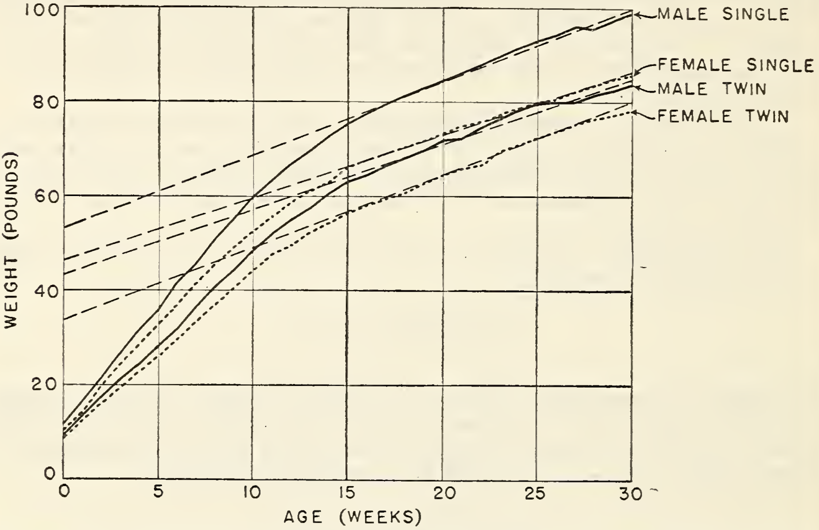

FIGURE 2.—Growth curves of Hampshire lambs living to 30 weeks of age (6 years' data at Beltsville, Md.). The broken lines represent the straight line of best fit of each curve between 15 and 30 weeks of age and when extended intercept the age axis at the points shown in the last column of table 1.

Data on all the lambs described in the preceding paragraph that survived to 1 year of age and similar data from the literature were used in extending the study to show how the method may be used in practice.

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[1] BYWATERS, JAMES H., and WILLHAM, OLIVER S. A METHOD OF COMPARING GROWTHINESS IN PIGS WEIGHED AT DIFFERENT AGES AND SUBJECTED TO DIFFERENT TREATMENTS. Amer. Soc. Anim. Prod. Proc. 28: 116–119, illus. 1935.

[2] WHATLEY, J. A., JR., and QUAIFE, E. L. ADJUSTING WEIGHTS OF PIGS TO A STANDARD AGE OF 56 DAYS. Amer. Soc. Anim. Prod. Proc. 30: 126–130, illus. 1937.

DATA AND DISCUSSION

ACCURACY OF METHODS OF ESTIMATING WEIGHTS

The growth curves for all the lambs that survived to 30 weeks in the Hampshire, Shropshire, and Southdown breeds and to 35 weeks in the Corriedale breed, in each of the type-of-birth and sex groups within each breed, are shown in figures 2 to 5. The straight line of best fit was computed for each of these curves for the sections between 15 and 30 weeks (20 to 35 in the Corriedale breed), and the intercepts of these lines on the age axis were determined. These intercepts are shown in the last column of table 1.

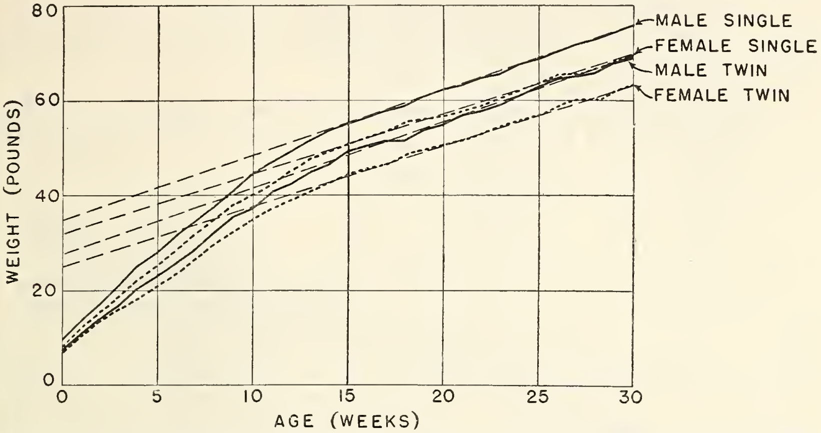

FIGURE 3.—Growth curves of Shropshire lambs living to 30 weeks of age (6 years' data at Beltsville, Md.). The broken lines represent the straight line of best fit of each curve between 15 and 30 weeks of age and when extended intercept the age axis at the points shown in the last column of table 1.

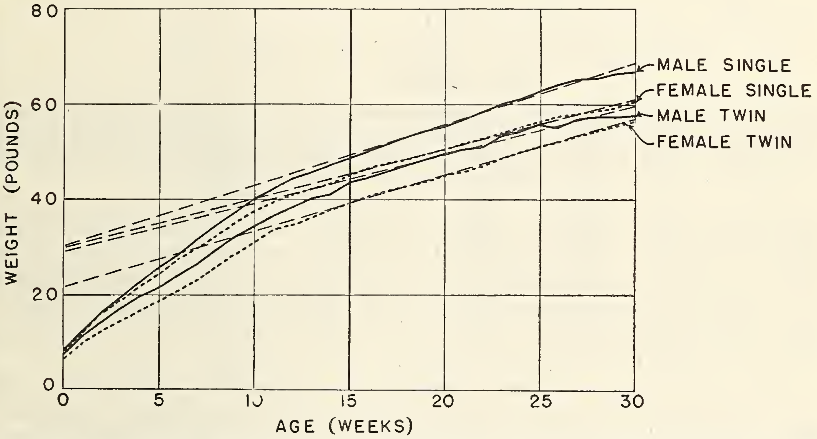

FIGURE 4.—Growth curves of Southdown lambs living to 30 weeks of age (6 years' data at Beltsville, Md.). The broken lines represent the straight line of best fit of each curve between 15 and 30 weeks of age and when extended intercept the age axis at the points shown in the last column of table 1.

The estimated weights of all lambs were then computed (1) on the basis of the average weekly gain and (2) along the slope of a line approximating the section of the growth curve involved, first by using the average intercept of the age axis (—27) and then using the actual intercept for each of the groups listed in table 1. The differences between these estimated weights and the actual weights at 20 weeks were then computed and the means of these differences were determined. These means, given in table 2, show the degree to which the weights computed by the methods described approached the actual weights at 20 weeks of age.

In all 16 groups, the weights estimated by the use of the average age intercept of —27 more nearly approached the actual weight at 20 weeks than did weights estimated on the basis of average weekly gains. In 13 of these groups the differences between the average deviations were statistically significant (using the level of significance of $p=0.05$). These data indicate the desirability of estimating weights along a line approximating the section of the growth curve involved rather than by the use of the average weekly gain.

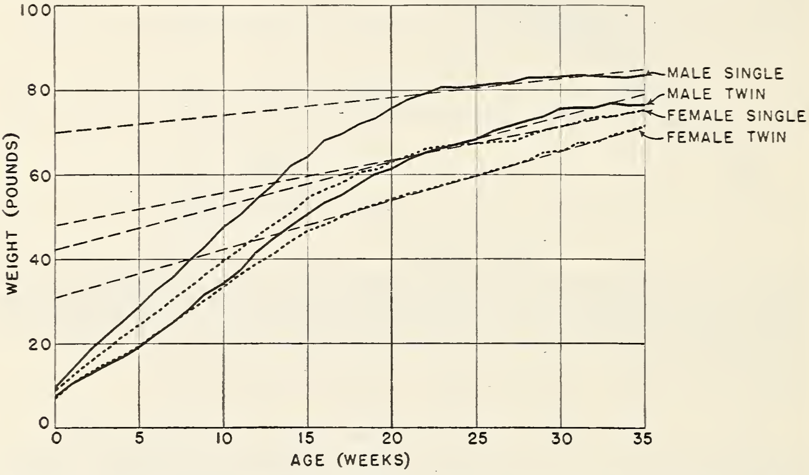

FIGURE 5.—Growth curves of Corriedale lambs living to 35 weeks of age (6 years' data at Beltsville, Md.). The broken lines represent the straight line of best fit of each curve between 20 and 35 weeks of age and when extended intercept the age axis at the points shown in the last column of table 1.

The question now arises: Would the estimated weights be still more accurate if the actual age intercept of each group had been used rather than the average intercept of —27? The use of actual intercepts reduced the average deviation of the differences between actual and adjusted weights in 10 of the 16 cases and increased it in 3. Three of the differences in which a decrease was effected were statistically significant. Two of these cases were those in which the age intercepts (—64 and —168) were considerably below the average intercept (—27). In the 3 remaining cases the results were not changed. There seems to be little advantage in the use of individual intercepts rather than an average one so long as the actual intercepts do not deviate too far from the average figure.

Table 1.—*Age intercepts of straight lines of best fit for the sections of the growth curve (figs. 2 to 5) approximating weaning age*

Breed	Type of birth	Sex	Animals	Section of growth curve	Age intercept
			Number	*Weeks*	*Weeks*
Hampshire	Single	Male	34	15 to 30	−35
		Female	38	15 to 30	−36
	Twin	Male	22	15 to 30	−31
		Female	38	15 to 30	−22
Shropshire	Single	Male	29	15 to 30	−26
		Female	23	15 to 30	−26
	Twin	Male	24	15 to 30	−20
		Female	33	15 to 30	−20
Southdown	Single	Male	39	15 to 30	−23
		Female	34	15 to 30	−29
	Twin	Male	17	15 to 30	−29
		Female	27	15 to 30	−19
Corriedale	Single	Male	23	20 to 35	[1] −168
		Female	33	20 to 35	[1] −64
	Twin	Male	11	20 to 25	−41
		Female	23	20 to 35	−26
Average intercept					−27

[1] Not included in average figure because of wide deviation from other data.

Table 2.—*Average deviations of estimated weights from actual weights of lambs and significance of differences between them*

Breed	Type of birth	Sex	Average deviations of estimated weights from actual weights when use was made of—			Significance of differences (*p* values) between—	
			Weights computed on basis of average weekly gain	Weights computed using average age intercept of −27	Weights computed using actual age intercept of each group	First two	Second and third
			Pounds	*Pounds*	*Pounds*		
Hampshire	Single	Male	6.79	4.30	4.14	<0.01	0.36
		Female	4.64	2.67	2.73	<.01	.92
	Twin	Male	5.43	4.20	4.19	.09	.89
		Female	3.92	2.34	2.36	<.01	.98
Shropshire	Single	Male	4.51	3.48	3.48	.08	
		Female	3.68	2.59	2.57	.04	.82
	Twin	Male	2.98	2.67	2.59	.38	.31
		Female	3.60	2.77	2.70	.02	.44
Southdown	Single	Male	3.30	2.51	2.32	.05	<.01
		Female	4.20	2.28	2.28	<.01	
	Twin	Male	2.78	2.03	2.03	.02	
		Female	2.85	2.06	2.00	.02	.59
Corriedale	Single	Male	13.36	6.13	3.90	<.01	.03
		Female	10.61	4.82	3.19	<.01	<.01
	Twin	Male	7.61	2.91	2.78	<.01	.79
		Female	6.24	2.68	2.71	<.01	.27

The variation from actual weights of the weights estimated by the most accurate method is apparently due to the variations in slope within the growth curves of individual lambs. Instead of an even rate of growth of the type found in the average growth curves, the individual often has considerable fluctuations above and below a smooth curve.

SHORT METHODS OF ESTIMATING WEIGHTS

In actual practice it is not necessary to solve the complete equation to compute the weight of each lamb. If the average age intercept of −27 is selected for use and the range of ages is 15 to 30 weeks, the factor $\left(\frac{20-A}{X-A}\right)$ for each age can be determined and set up in tabular form (table 3). The only necessary calculation is to multiply the actual weight of the lamb by the factor which appears opposite its age in the following tabulation. A similar table can be prepared for any specific age intercept that fits the data to be adjusted and for correcting to ages other than 20 weeks. This formula can be used for computing weights at any constant age so long as the section of the growth curve represented in the age range of the individuals involved approximates a straight line.

Factors for adjusting weights of lambs taken at varying ages to a constant age of 20 weeks [1]

Age of lamb (weeks):	*Factor*
15	1.119
16	1.093
17	1.068
18	1.044
19	1.022
20	1.000
21	.979
22	.959
23	0.940
24	.922
25	.904
26	.887
27	.870
28	.854
29	.839
30	.825

[1] Multiply actual weight by factor opposite actual age of lamb. These factors are based on an age intercept of −27 weeks.

TABLE 3.—*Age intercepts of straight lines of best fit for the sections of growth curves approximating weaning age (20 weeks)*

Breed	Type of birth	Sex [1]	Animals	Based on growth data from—	Section of growth curve used	Age intercept
			Number		*Weeks*	*Weeks*
Hampshire	Single	Male	23	Beltsville, Md.[2]	15 to 30	−24.5
		Female	27	do	15 to 30	−31.5
	Twin	Male	13	do	15 to 30	−29.8
		Female	33	do	15 to 30	−23.7
Shropshire	Single	Male	18	do	15 to 30	−28.7
		Female	15	do	15 to 30	−17.9
	Twin	Male	11	do	15 to 30	−18.2
		Female	25	do	15 to 30	−21.0
Southdown	Single	Male	26	do	15 to 30	−19.1
		Female	29	do	15 to 30	−21.4
	Twin	Male	10	do	15 to 30	−28.8
		Female	26	do	15 to 30	−18.1
Corriedale	Single	Male	15	do	20 to 35	−64.6
		Female	28	do	20 to 35	−53.4
	Twin	Male	7	do	20 to 35	−29.6
		Female	18	do	20 to 35	−22.2
Hampshire	Single and twin.	Male	18	Foster	20 to 35	−48.2
		Female	31–42	do	20 to 35	−71.8
Shropshire	do	Male	17	do	20 to 35	−30.7
		Female	30–33	do	20 to 35	−39.9
Southdown	do	Wether	14	do	20 to 35	−78.5
Suffolk	Single	Female	17–53	Hammond	20 to 35	−37.2
	Twin	do	45–165	do	20 to 35	−22.3
Welsh Mountain	Single and twin.	Male and female.	27–85	Phillips	16 to 25	−35.4
Merino	Single	Male	27–29	Bell, Spencer, and Hardy.	19 to 24	−19.5
		Female	22	do	19 to 24	−76.8
	Twin	Male	13–14	do	19 to 24	−18.3
		Female	19–20	do	19 to 24	−34.5
Merino×Shropshire	Single	Male	8–18	Hammond	15 to 30	−14.8
		Female	2–22	do	15 to 30	−19.8
	Twin	Male	3–9	do	15 to 30	−3.1
		Female	5–16	do	15 to 30	−11.2

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[1] Unless otherwise designated, males are uncastrated rams.

[2] The data from Beltsville, Md., were obtained by various investigators of the Bureau of Animal Industry and were assembled and analyzed, for the present study, by the authors of this publication.

The application of the equation can be still further simplified, as shown in figure 6. In this figure, the weights of five lambs are estimated by placing a straightedge between the age intercept (*a*) and the point, on the graph, representing the actual weight of the animal at time of weighing. If a constant age of 20 weeks is selected, the point at which this line crosses the line perpendicularly to 20 weeks of age will be the estimated weight. On a graph of this type weights can easily be read to the nearest pound, or to the nearest half-pound if desired.

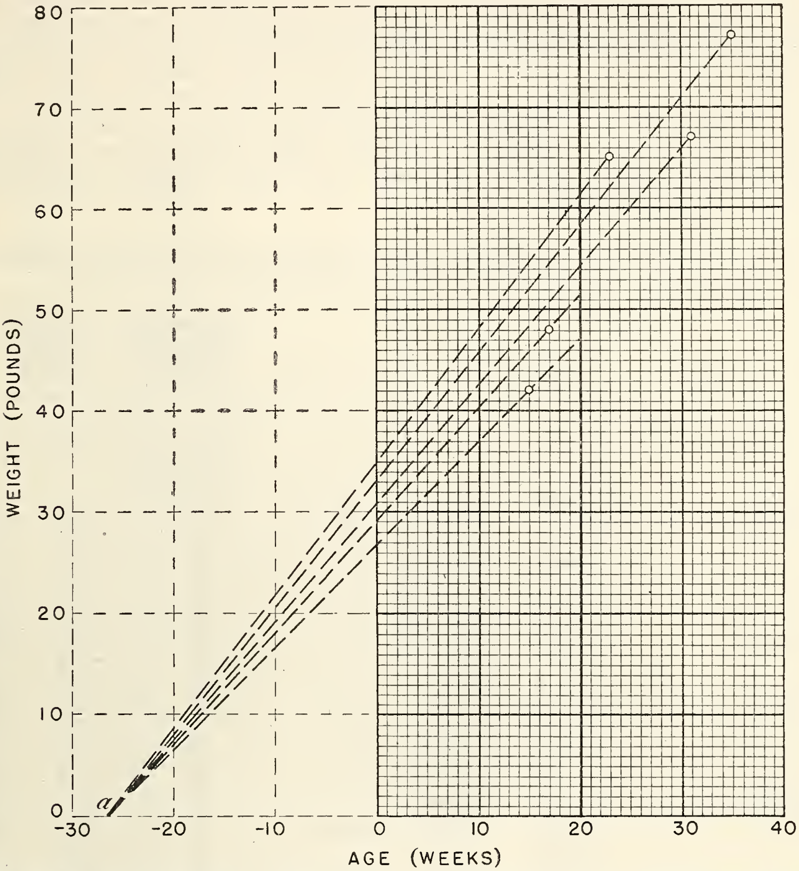

Figure 6.—Illustrating a quick method of estimating, at a constant age of 20 weeks, the weights obtained at various ages of lambs. *a*, Age intercept selected; circles, unadjusted weights of five individual lambs; and broken lines represent straightedges laid between the two points. The estimated weight is read at the point where the straightedge intercepts the line perpendicular to 20 weeks of age.

In applying the results, it is essential to know whether they are typical of growth data in general, or whether different results will obtain for sheep of other breeds and reared under other conditions. The experimenter or breeder may also wish to adjust to a constant age other than 20 weeks; hence, data at later stages in development are of interest. The data on all the lambs used in this study that lived to 52 weeks were tabulated to that age, the average growth data being presented in table 6, and all growth data from the literature that were in such form that they could be used for this work were assembled. From these data the slope of the growth curve was determined for the sections of approximately 20, 40, and 52 weeks. The intercepts on the age axis are given in table 3 for the sections of the curves approximating 20 weeks, and in table 4 for the 40- and 52-week sections of the growth curves. In all cases in which weekly weights were available, data from 37 to 43 weeks, inclusive, were used in determining the slopes of growth curves of about 40 weeks, and data from 48 to 52 weeks were used for the slopes of growth curves of about 52 weeks. In Foster's data, for which weights were available at approximately monthly intervals, the three weights nearest to 40 and to 52 weeks were used.

TABLE 4.—*Age intercepts of straight lines of best fit for use in estimating weights of lambs at 40 and 52 weeks of age*

Breed	Type of birth	Sex [1]	Source of data	Individuals on which growth data were available at—		Intercepts for use in estimating weights at—	
				40 weeks	52 weeks	40 weeks	52 weeks
				Number	*Number*		
Hampshire	Single	Male	Beltsville, Md.[1]	23	23	−20.5	−19.1
		Female	do	27	27	−18.8	−15.4
	Twin	Male	do	13	13	−3.8	−.4
		Female	do	33	33	−17.3	−6.4
Shropshire	Single	Male	do	18	18	−9.4	−1.1
		Female	do	15	15	−31.8	−8.6
	Twin	Male	do	11	11	−5.0	−2.3
		Female	do	25	25	−16.1	−8.6
Southdown	Single	Male	do	26	26	−15.8	−43.0
		Female	do	29	29	−13.4	−30.5
	Twin	Male	do	10	10	−28.3	−10.0
		Female	do	26	26	−5.8	−12.4
Corriedale	Single	Male	do	15	15	−9.4	−24.6
		Female	do	28	28	−20.3	−35.2
	Twin	Male	do	7	7	−11.4	−17.5
		Female	do	18	18	−39.0	−57.8
Hampshire	Single and twin.	Male	Foster	18	18	−36.3	−80.0
		Female	do	31	31	−87.2	−38.4
Shropshire	do	Male	do	17	17	−6.8	−35.2
		Female	do	30	30	−60.5	−31.8
Southdown	do	Wether	do	14	14	−25.7	−15.0
Suffolk	Single	Female	Hammond	34	32	−102.4	−206.8
	Twin	do	do	46	45	−83.6	−87.6
Merino×Shropshire	Single	Male	do	18	18	−38.3	−63.1
		Female	do	23	22	−30.5	−73.8
	Twin	Male	do	9	9	−40.5	−44.4
		Female	do	16	16	−14.9	−25.1

[1] See footnotes to table 3.

Growth data from the following sources were taken from the literature: Hammond,[3] who presents data on Suffolk and on Merino× Shropshire lambs reared in the experimental flocks of the University of Cambridge, England; Foster,[4] who presents data on Hampshire, Shropshire, and Southdown lambs in the flocks of the Missouri Agricultural Experiment Station; Phillips,[5] who presents data on Welsh

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[3] HAMMOND, JOHN. GROWTH AND THE DEVELOPMENT OF MUTTON QUALITIES IN THE SHEEP; A SURVEY OF THE PROBLEMS INVOLVED IN MEAT PRODUCTION. 597 pp., illus. Edinburgh and London. 1932.

[4] FOSTER, M. T. THE GROWTH OF SHEEP. Mo. Agr. Expt. Sta. Res. Bul. 96: 122–123, illus. 1926.

[5] PHILLIPS, R. RATE OF GROWTH IN LAMBS. Welsh Jour. Agr. 4: 121–141. 1928.

Mountain sheep reared at Nantcellan, Wales; and Bell, Spencer, and Hardy,[6] who report growth data on Merino lambs reared at the Ohio Agricultural Experiment Station. In the last two cases the data were reported by dates and hence were relisted by ages before carrying out the calculations. Growth data on sheep at Beltsville, from which the age intercepts for the sections of the growth curve approximating 20, 40, and 52 weeks, presented in tables 3 and 4, were calculated, are summarized in table 5.

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[6] Bell, D. S., Spencer, D. A., and Hardy, J. I. THE INFLUENCE OF VARIOUS FACTORS UPON THE GROWTH AND QUALITY OF FINE WOOL AS OBTAINED FROM MERINO SHEEP. Ohio Agr. Expt. Sta. Bul. 571, 57 pp., illus. 1936.

TABLE 5.—*Weight data from which the age intercepts of Beltsville sheep presented in tables 3 and 4 were calculated*

Age (weeks)	Hampshire				Shropshire				Southdown				Corriedale			
	Single male	Single female	Twin male	Twin female	Single male	Single female	Twin male	Twin female	Single male	Single female	Twin male	Twin female	Single male	Single female	Twin male	Twin female
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	11.3	10.0	9.9	9.0	9.7	8.4	7.8	7.1	8.6	7.9	8.0	6.7	9.6	8.8	8.2	7.2
1	15.4	15.8	14.3	13.0	14.9	12.5	11.4	10.4	13.2	12.1	12.1	10.1	14.3	12.5	10.9	10.3
2	21.3	20.1	17.8	16.5	18.2	16.1	14.9	13.6	17.1	16.2	14.8	12.8	18.2	15.4	12.9	12.7
3	26.6	24.1	21.5	19.8	22.4	19.7	18.0	15.6	20.5	18.5	17.6	14.7	22.1	18.1	14.9	14.8
4	31.1	28.4	24.8	23.1	26.3	22.5	20.8	18.1	24.1	21.8	20.5	16.7	25.5	21.4	16.9	16.8
5	35.3	32.8	29.5	26.2	28.8	25.7	23.3	20.6	26.8	24.5	23.3	18.8	28.8	24.1	19.9	19.3
6	41.1	36.9	32.3	30.4	32.2	29.3	26.0	23.2	29.4	27.5	26.8	20.8	32.8	27.3	22.7	22.0
7	45.0	41.4	37.6	34.2	35.7	32.1	29.7	26.4	32.7	29.6	29.7	23.3	36.3	30.1	26.6	24.9
8	50.2	45.9	41.8	37.8	38.9	35.7	32.2	29.3	35.7	32.2	33.3	26.0	40.0	33.4	30.6	27.6
9	54.7	49.9	45.4	41.4	42.0	38.1	35.8	32.3	38.5	34.7	35.8	28.3	43.5	36.5	33.9	30.4
10	59.1	53.1	50.2	45.4	45.1	39.8	37.9	34.8	41.3	36.8	38.0	31.1	47.9	40.0	36.6	33.6
11	63.6	56.4	54.0	48.6	48.1	42.5	41.5	37.1	43.7	38.8	40.4	33.3	50.0	42.5	39.9	35.9
12	66.3	59.3	58.3	50.9	49.3	45.3	43.2	38.4	45.8	40.4	41.9	34.1	54.3	46.0	45.1	39.2
13	69.4	61.6	60.3	53.4	52.3	47.3	45.6	40.4	47.2	41.6	43.9	36.1	57.2	48.6	47.7	41.2
14	72.6	63.9	63.8	55.5	53.8	48.8	46.9	42.6	48.8	43.1	45.5	37.4	62.2	51.5	51.9	44.5
15	75.1	66.9	66.2	57.5	55.6	50.4	50.1	44.4	49.9	44.7	47.6	38.8	63.4	54.6	54.1	46.3
16	77.5	68.7	68.1	59.4	56.9	51.3	51.2	45.8	51.7	46.3	48.9	40.5	67.7	57.0	57.3	47.7
17	78.8	70.1	69.9	60.7	58.3	52.3	52.7	46.7	53.5	47.2	50.4	41.5	69.4	58.3	59.4	49.4
18	81.3	71.1	71.3	62.2	60.3	54.7	53.6	48.5	55.0	48.2	51.1	43.0	72.9	60.3	62.7	51.6
19	83.0	72.7	72.8	64.1	62.2	55.5	54.9	49,3	56.4	49.3	52.4	43.5	74.7	60.9	65.6	52.6
20	84.4	73.8	76.2	66.2	63.1	57.1	56.1	50.6	57.0	50.3	52.9	44.9	77.5	63.8	67.3	54.5
21	86.7	75.6	75.8	67.2	63.7	58.1	58.1	51.4	58.5	52.0	54.3	45.7	79.4	65.5	70.0	55.8
22	88.0	76.7	77.5	67.8	65.4	59.9	57.5	53.5	60.6	53.0	54.7	47.1	80.5	66.5	71.9	56.3
23	90.3	78.6	79.5	70.7	65.7	61.1	60.5	54.6	62.2	54.3	56.9	48.8	81.3	66.8	72.3	58.4
24	92.8	80.2	81.9	71.8	66.9	63.6	62.9	56.5	63.7	55.8	58.1	49.7	80.5	67.1	72.4	59.2
25	94.7	80.9	83.3	73.6	68.6	65.4	64.2	56.9	65.3	57.1	59.6	51.4	80.5	68.0	73.9	59.3
26	96.1	82.5	84.1	74.8	69.5	66.8	65.9	58.9	67.0	58.4	58.5	52.2	83.0	68.6	75.9	61.6
27	99.2	84.4	84.2	76.1	72.0	67.3	66.5	59.7	68.7	59.6	61.2	53.5	83.7	68.7	77.7	62.2
28	99.3	86.0	86.5	77.5	72.4	69.5	69.4	59.5	69.6	60.7	62.1	54.6	85.2	70.0	77.3	63.6
29	101.7	87.3	86.8	78.4	74.4	71.9	70.3	61.5	70.6	61.6	63.0	55.5	86.1	71.6	79.6	65.6
30	103.8	88.3	89.2	79.7	75.1	71.9	71.7	63.1	71.7	62.9	64.2	56.5	87.5	72.6	81.6	65.8
31	106.7	91.3	89.5	82.3	76.4	74.3	74.2	64.9	74.0	63.4	65.5	57.5	88.3	73.7	83.7	68.3
32	108.6	92.2	89.5	84.3	78.1	75.6	76.5	66.3	74.7	65.0	67.1	59.1	89.0	74.7	83.1	68.5
33	110.2	93.6	92.5	85.5	79.9	77.1	78.4	68.5	75.9	65.5	67.5	60.3	89.6	75.4	86.4	70.8
34	110.9	95.5	94.2	88.0	82.1	78.3	80.8	70.1	77.7	67.1	68.3	61.3	90.8	76.5	87.0	72.3
35	113.1	97.3	95.8	88.8	83.8	79.7	82.2	71.6	79.4	68.4	70.1	62.7	91.3	77.1	88.7	73.9
36	114.5	99.4	98.0	90.7	86.6	81.7	84.4	71.3	81.2	69.7	71.5	63.8	93.3	79.2	90.7	75.0
37	116.0	100.0	101.8	92.3	88.8	83.3	85.8	72.0	82.5	70.3	73.6	64.1	95.2	80.3	94.3	77.3
38	118.0	102.4	103.7	93.4	90.8	85.3	88.3	73.6	84.3	71.6	74.5	65.3	97.3	82.6	96.7	79.1
39	119.7	103.5	106.2	94.8	92.7	86.4	90.6	74.3	85.4	73.2	76.0	67.0	99.5	84.4	99.7	79.3
40	121.5	105.1	109.8	96.5	95.4	87.4	92.2	75.7	87.3	74.3	76.9	68.0	101.9	86.3	102.3	81.2
41	124.0	107.7	112.5	98.3	96.9	88.5	94.7	76.8	89.1	76.0	77.6	69.8	103.5	86.7	103.6	81.5

42	126.2	108.9	114.4	100.6	98.9	89.9	96.4	78.7	90.1	77.1	78.8	70.9	105.3	87.9	104.1	82.1
43	127.9	111.0	115.8	102.1	99.9	90.9	98.2	80.4	92.0	78.7	80.7	72.6	107.7	89.2	106.4	84.1
44	130.0	112.7	118.5	104.9	103.1	92.5	100.6	82.3	93.0	80.0	82.3	73.8	109.3	90.9	108.9	85.4
45	131.0	114.5	120.9	106.3	104.3	93.5	103.4	83.3	95.4	81.8	84.7	75.3	111.9	92.0	111.7	86.6
46	132.6	115.6	124.2	107.3	106.7	95.9	105.7	85.4	97.1	82.9	85.7	77.3	113.8	92.9	113.4	87.6
47	135.6	117.8	127.0	110.1	109.2	97.2	107.0	86.3	98.9	84.2	89.6	78.2	116.5	94.8	113.7	89.8
48	137.9	119.3	130.8	111.2	111.6	98.9	108.7	87.8	100.2	85.1	89.2	79.0	117.1	96.4	115.4	92.1
49	139.9	120.9	135.3	112.8	114.9	101.4	111.0	89.5	101.3	87.0	89.7	80.7	117.9	98.0	118.1	92.9
50	143.2	122.8	137.3	114.9	116.2	102.1	114.8	90.7	102.3	88.3	91.7	81.9	120.4	98.9	120.7	93.6
51	144.7	124.5	140.1	117.2	118.3	104.1	115.9	92.4	103.6	88.5	92.8	82.8	121.6	100.0	120.6	95.2
52	145.8	126.9	142.0	119.2	121.3	106.3	117.1	94.1	104.1	89.8	95.3	84.5	123.3	101.2	123.0	95.3

The averages of all the age intercepts presented in tables 3 and 4 for use in estimating weights at the constant ages of 20, 40, and 52 weeks are −31.7, −29.4, and −36.8, respectively. There is considerable variation in the slope of the growth curves at each stage in the various groups. These variations are probably due to differences in inherited ability to grow, differences in environment, and inaccuracies due to the small numbers involved in many cases. The average intercepts for each breed at each experiment station from which data were available are presented in table 6. These are arithmetic averages for data on lambs of different sexes and types of birth presented in tables 3 and 4. In only two cases, the Hampshire and Shropshire groups, are direct comparisons proper between data collected at Beltsville and at other stations. It is obvious that the lambs of these two breeds that were reared at Beltsville were gaining in weight more rapidly during the three periods studied than the lambs for which data were reported by Foster. The Southdown data from Beltsville and those reported by Foster are not comparable since the former data include rams and ewes and the latter only wethers which were retained for special purposes beyond the age at which wethers are usually marketed.

TABLE 6.—*Average age intercepts of straight lines of best fit for the sections of the growth curves approximating 20, 40, and 52 weeks for each of the breed groups presented in tables 3 and 4*

Breed	Based on growth data from—	Age intercept for period approximating—		
		20 weeks	40 weeks	52 weeks
		Weeks	*Weeks*	*Weeks*
Hampshire	Beltsville [1]	−27.4	−15.1	−10.3
	Foster	−60.0	−61.8	−59.2
Shropshire	Beltsville	−21.4	−15.6	−5.2
	Foster	−35.3	−33.6	−33.5
Southdown	Beltsville	−21.8	−15.8	−24.0
	Foster	−78.5	−25.7	−15.0
Corriedale	Beltsville	−42.4	−20.0	−33.8
Suffolk	Hammond	−29.8	−93.0	−147.2
Merino×Shropshire	do	−12.2	−31.0	−51.6
Merino	Bell, Spencer, and Hardy	−37.3		
Welsh Mountain	Phillips	−35.4		

[1] See footnote 2 to table 3.

The three Down breeds reared at Beltsville show close agreement in the intercepts at 20 and 40 weeks, but at 52 weeks the Southdown intercept was considerably below that of the other two breeds, indicating that the Southdown lambs were not growing as rapidly at this age.

The intercepts for the Corriedales were somewhat lower than those for the Down breeds at 20 and 40 weeks, and lower than the intercepts for the Hampshires and Shropshires at 52 weeks.

The intercepts for Suffolks and Merino×Shropshires, based on Hammond's data, indicate a relatively rapid rate of growth at the 20-week stage and a lower rate at the later stages, particularly in the Suffolk breed. Intercepts for the Merino and Welsh Mountain breeds at 20 weeks fall within the range of intercepts of the other breeds at that age.

From the data at hand it is not possible to determine how much of the variation in the intercepts is due to differences in breed and how much to differences in environment. Data on growth in sheep are quite limited, and those available are on animals reared at experiment stations, essentially under farm-flock conditions, but where the level of nutrition is probably higher than in the average farm flock. Since the data at hand are too limited to give a representative picture of the growth rate of lambs at experiment stations, and since no data are available for animals reared under actual farm-flock conditions, it is not possible to indicate an intercept that will be most accurate for any given set of conditions other than those existing at the experiment stations from which growth data were available. However, all the intercepts determined in this study fall on the negative side of the time of birth and the average of all of these figures would give an intercept which, when used in estimating weights, would give more accurate results than would be obtained by estimating on the basis of average weekly gain. The average figures for all the data, given previously, namely −31.7, −29.4, and −36.8, may for convenience be rounded to −30, −30, and −35 for estimating weights at the ages of 20, 40, and 52 weeks, respectively.

If one is working with one of the breeds used in this study, the intercept for that breed could be used instead of the general average for all the breeds studied. If weight data are available at one or more ages the individual worker can determine whether the growth of his animals approximates that of the animals for which data are given or referred to in this circular and use this information in selecting an intercept.

The main objective of this circular has been to present a method of estimating weights of lambs at constant ages and to show the advantages of its use. Available growth data have been summarized for use in applying the method, but there is obvious need for more data on the growth of different types of sheep under various conditions before the most accurate application of the method can be made.

SUMMARY

Weights of lambs at constant ages are often needed in experimental work and are useful in sheep-breeding work for comparing individuals and groups of progeny sired by different rams. It is seldom practicable to weigh each lamb when it reaches a definite age; hence, it is highly desirable to know the most accurate method by which weights of lambs, taken at a time when the ages of the lambs approximate the constant age to be used, can be estimated at that constant age.

Using weights obtained at various ages, it is shown that weights at a constant age of 20 weeks can be estimated more accurately along the slope of the growth curve in the vicinity of that age, than by estimating by the use of average weekly gains. The formula used in the more accurate method is

$$Z\left(\frac{20-A}{X-A}\right)=Y,$$

in which Y=estimated weight, Z=actual weight, 20=constant age, A=age intercept, and X=actual age. For constant ages other than 20 weeks, the figure 20 would be replaced by the age being used. The age intercept is the point at which a line, representing the slope of the growth curve in the vicinity of the constant age, intercepts the age axis.

The solution of the formula for each lamb is not necessary in practice. Two short cuts are outlined. In one, the weight of the lamb is simply multiplied by a predetermined factor. In the second, the estimated weight is read directly from a chart designed for that purpose.

Available growth data from this study and from the literature have been used for calculating age intercepts, and these intercepts are presented for use in applying the method for estimating weights at 20, 40, and 52 weeks of age. There is, however, obvious need for more data on the growth of sheep of different types and under various conditions before the most accurate application of the method can be made.

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